THE OHIO STATE UNIVERSITY

The After Fracking Problem in Arkansas: Cause of an Exaggerated Presence of Earthquake

by John Nsona

INTRODUCTION

•Starting 2009, areas of central and eastern United States witnessed increased incidences of earthquakes.
•More than 500 small earthquakes with a magnitude of between 1.8 and 3.8 on the Richter scale rattled Guy and Greenbrier in north-central Arkansas (Ellsworth, 2013).
•The earthquakes were occurring within a 6km radius and supposedly caused by drilling activities linked to exploration and production of oil and shale gas in Fayetteville Shale.
•Analyzes established a substantial correlation between the drilling and the earthquakes.
•Also, disposal of drilling wastes was a possible cause of the earthquakes through hydraulic fracturing.

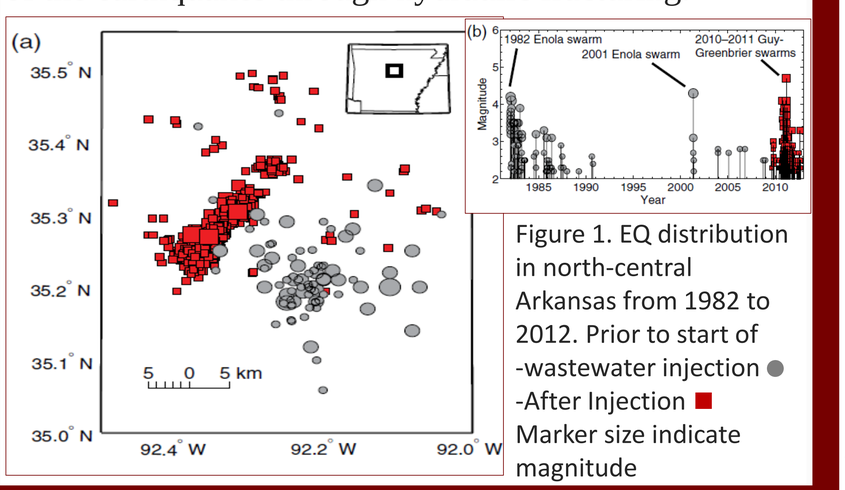

Figure 1. EQ distribution in north-central Arkansas from 1982 to 2012. Prior to start of -wastewater injection ● -After Injection ■ Marker size indicate magnitude

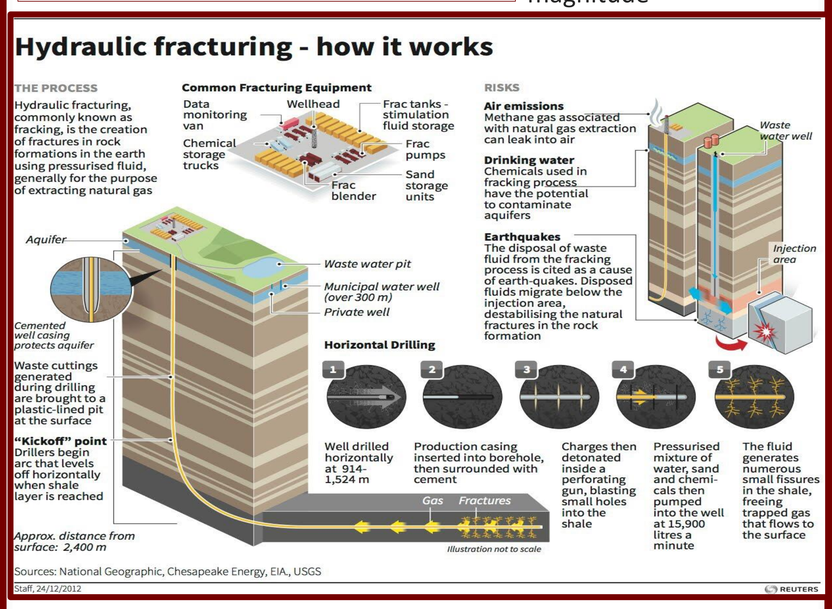

Figure 2. gives a quick overview of hydraulic fracturing (Reuters)

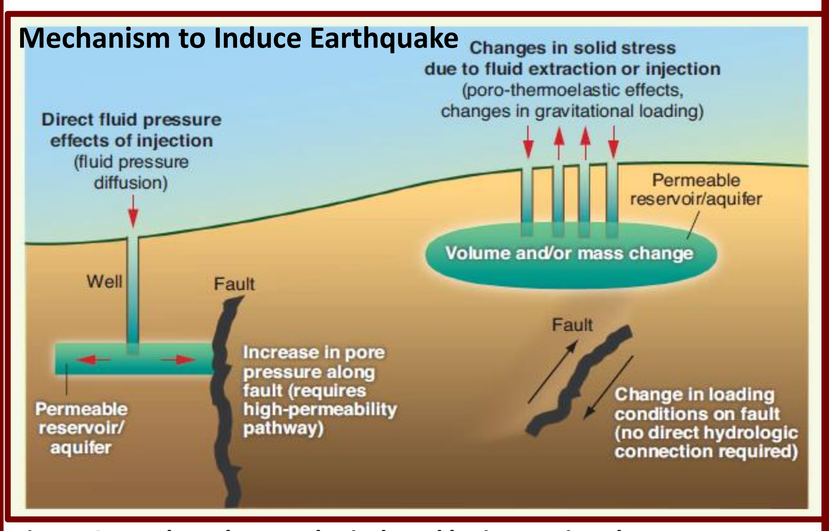

Figure 3. Earthquakes can be induced by increasing the pore pressure acting on a fault (left) or by changing the shear and normal stress acting on the fault (right).

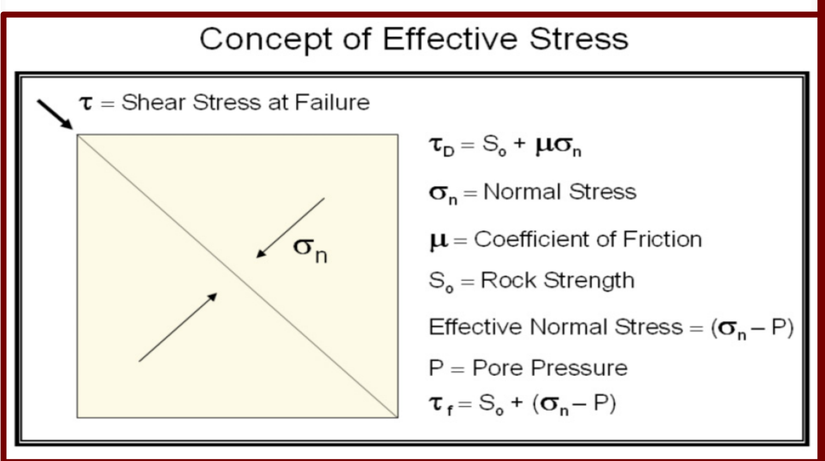

Figure 4. The diagonal line is the plane of fault. The two opposing arrows are the forces that hold the fault in place keeping it from slipping. Tau is the point at which fault occurs. As the pore pressure P, increases the normal stress lowers because the pore pressure act counter to normal stress thus lower effective stress so, EQs occur.

OBJECTIVES

•The explanations offered by scientists about the fracking and increased seismic in Arkansas caused more puzzles than answers.
•No convincing agreements have been reached on the incidence of earthquake waves in the region which motivates a research and it is for the interest of this presentation that we investigates the implication and probable causes of the increased causes of earthquakes in Arkansas starting 2009.

METHODS & EVALUATION

•The study analyzes the occurrence times and magnitude of earthquakes that have already occurred before and after the oil and gas exploration.
•This is for the purpose of inquiring into the rate of change in the incidence of earthquakes in Arkansas.
•The data is obtained from the Advanced National Seismic System (ANSS) catalog that contains earthquake events that occurred between January 1982 and November 2012 with magnitude of ≥ 2.2≥.
•The ANSS catalog has a lower magnitude of completeness estimated with the MAXC algorithm to be 2.1 ± 0.06 which help to statistical analyze even more events using Epidemic-type aftershock (ETAS) model which helps to established if the rate changes are due to the fracking activity of the region, increase in background seismic rate, aftershock of productivity or just a all in one effect.

Arkansas ETAS Maximum Likelihood Estimation (MLE) Results

Data Set	μ (Events/Day)	K (Events/Day)	c (Days)	α	p	AIC
1982–2008	0.001 ± 0.01	0.028 ± 0.028	0.004 ± 0.003	0.92 ± 0.14	0.96 ± 0.02	680.33
μ estimated*	0.001 ± 0.007	0.082	0.046	1.09	1.27	749.66
2009–2012	0.016 ± 0.025	0.082 ± 0.007	0.046 ± 0.019	1.09 ± 0.03	1.27 ± 0.02	37.17
μ estimated†	0.032 ± 0.026	0.028	0.004	0.92	0.96	342.46
K estimated†	0.001	0.062 ± 0.005	0.004	0.92	0.96	141.57
μ and K estimated†	0.007 ± 0.026	0.061 ± 0.006	0.004	0.92	0.96	117.95
μ, K, α estimated†	0.007 ± 0.026	0.052 ± 0.012	0.004	1.24 ± 0.06	0.96	115.66
μ, K, c estimated†	0.007 ± 0.024	0.062 ± 0.007	0.004 ± 0.007	0.92	0.96	119.65
μ, K, p estimated †	0.011 ± 0.015	0.061 ± 0.006	0.004	0.92	1.05 ± 0.04	89.24
μ, K, α, p estimated †	0.011 ± 0.026	0.055 ± 0.010	0.004	1.12 ± 0.07	1.04 ± 0.01	89.49
μ, K, c, p estimated †	0.016 ± 0.025	0.089 ± 0.012	0.046 ± 0.032	0.92	1.27 ± 0.02	36.50
μ, K, c, α estimated †	0.007 ± 0.026	0.052 ± 0.011	0.005 ± 0.009	1.25 ± 0.06	0.96	117.16

Uncertainties are 1 standard deviation.
*All other parameters held constant at 2009–2012 estimates to evaluate impact of parameter changes.
†All other parameters held constant at 1982–2008 estimates to evaluate impact of parameter changes.

Table 1.

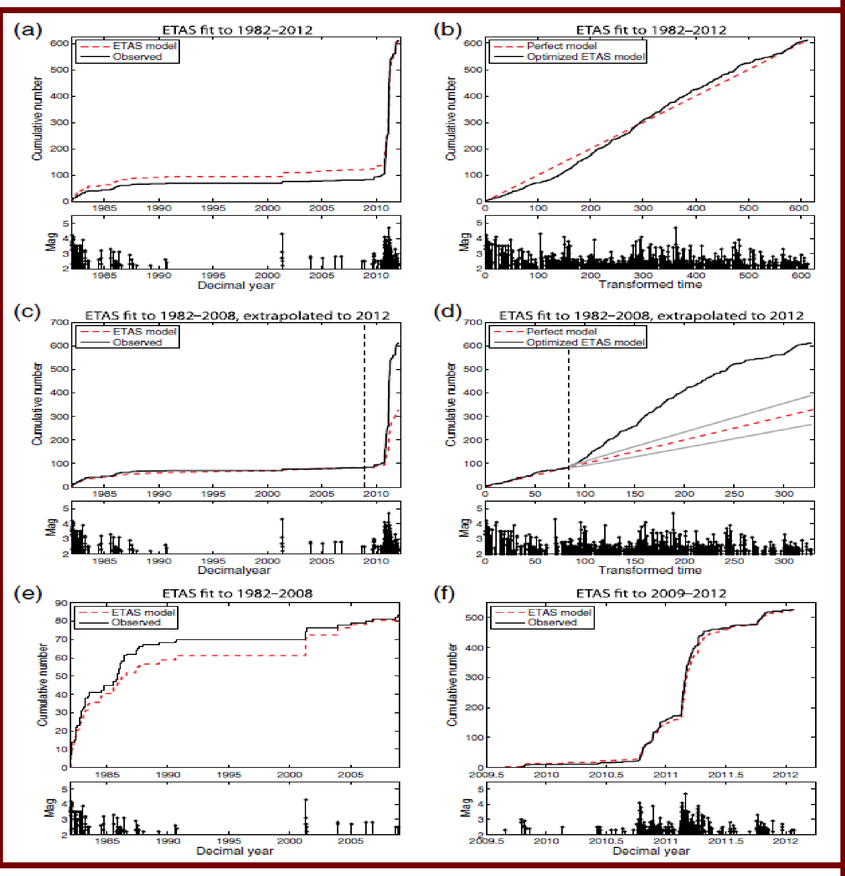

Figure 5. ETAS Modeling Result

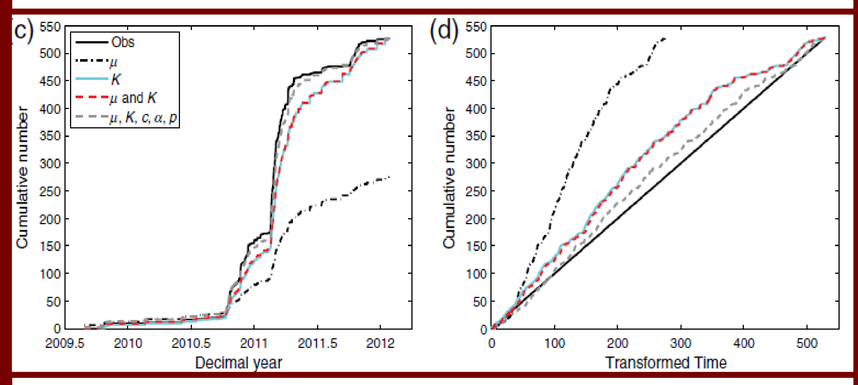

Figure 6. Diagram of cumulative number of events vs year and transformed Time

RESULTS

•Based on the results derived from the ETAS model, a change is required in the background seismicity rate and triggering parameters Arkansas •This is necessary so as to account for the substantial increase in seismicity following the 2009 earthquake swarms. •The results suggest that natural disaster swarms are time-dependent and are caused by changes in the pore fluid pressure arising from fluid migration. •The seismicity of Arkansas offers an exploration path as to how swarms triggered by natural processes are different from earthquakes caused by fluid ejection.

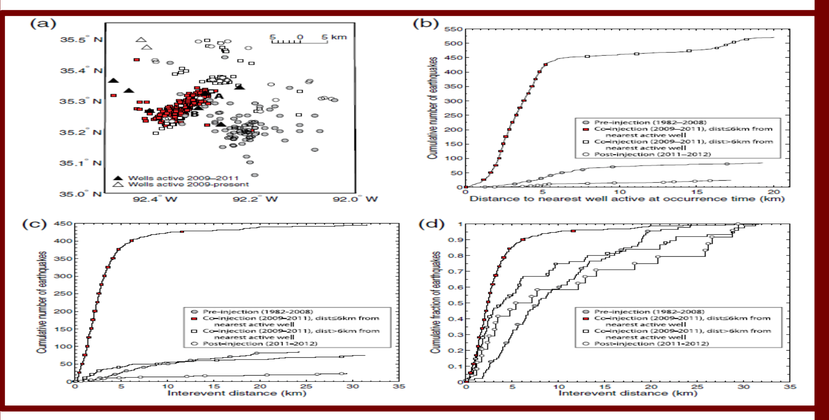

Figure 7. Comparison of EQ and Injection well locations

Arkansas Swarm Comparison

Data Set	μ (Events/Day)	K (Events/Day)	c (Days)	α	p	AIC
Enola, 1982–1987	0.007 ± 0.025	0.030 ± 0.034	0.002 ± 0.018	0.71 ± 0.19	0.95 ± 0.03	470.77
μ estimated*	0.010 ± 0.014	0.082	0.061	1.08	1.39	462.77
Guy–Greenbrier, 2010–2012	0.095 ± 0.618	0.082 ± 0.079	0.061 ± 0.284	1.08 ± 0.67	1.39 ± 0.3	−133.98
μ estimated†	0.204 ± 0.038	0.030	0.002	0.71	0.95	142.79
K estimated†	0.007	0.064 ± 0.006	0.002	0.71	0.95	−18.06
μ and K estimated †	0.013 ± 0.051	0.063 ± 0.006	0.002	0.71	0.95	−16.52
μ, K, α estimated †	0.015 ± 0.053	0.049 ± 0.016	0.002	1.22 ± 0.07	0.95	−24.03
μ, K, c estimated †	0.011 ± 0.049	0.067 ± 0.006	0.003 ± 0.008	0.71	0.95	−21.996
μ, K, p estimated †	0.026 ± 0.061	0.062 ± 0.006	0.002	0.71	1.01 ± 0.01	−33.81
μ, K, α, p estimated †	0.028 ± 0.098	0.051 ± 0.024	0.002	1.13 ± 0.09	1.01 ± 0.03	−38.50
μ, K, c, p estimated †	0.089 ± 0.055	0.096 ± 0.011	0.059 ± 0.007	0.71	1.39 ± 0.02	−130.67
μ, K, c, α estimated †	0.012 ± 0.048	0.052 ± 0.006	0.004 ± 0.004	1.24 ± 0.03	0.9457	−30.46

Uncertainties are 1 standard deviation.
*All other parameters held constant at 2010–2012 estimates to evaluate impact of parameter changes.
†All other parameters held constant at 1982–1987 estimates to evaluate impact of parameter changes.

Table 2.

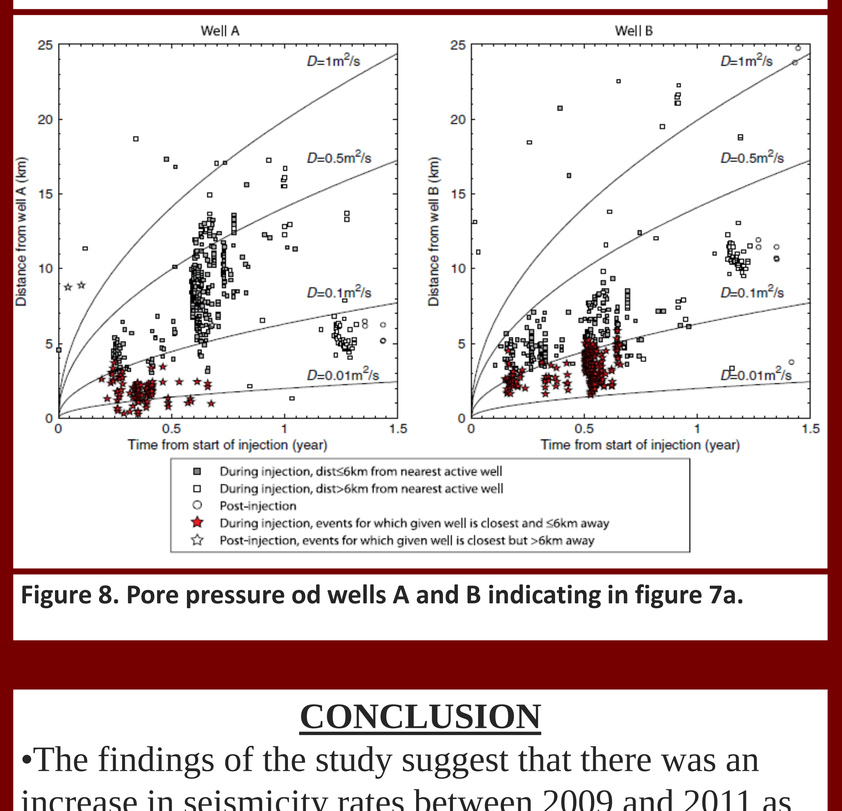

Figure 8. Pore pressure od wells A and B indicating in figure 7a.

CONCLUSION

•The findings of the study suggest that there was an increase in seismicity rates between 2009 and 2011 as compared to a period between 1975 and 2008.
•The increased seismicity led to higher incidence of earthquake swarms in Arkansas.
•This is different from the swarms that occurred between 1975 and 2008.
•Therefore, we can infer that increased oil and gas drilling in Arkansas is associated with increased seismicity, which consequently results to earthquakes.

REFERENCES

Campbell, K. W., and David M. Hampson. Processed digital recordings for selected earthquakes of the 1982 Enola, Arkansas, swarm. Denver, Colo.: Dept. of the Interior, U.S. Geological Survey :, 1989.

Ellsworth, W. L. (2013). Injection-induced earthquakes. Science, 341(6142), 1225942.

Horton, S. (2012). Disposal of hydrofracking waste fluid by injection into subsurface aquifers triggers earthquake swarm in central Arkansas with potential for damaging earthquake. Seismological Research Letters, 83(2), 250-260.

Llenos, A. L., & Michael, A. J. (2013). Modeling earthquake rate changes in Oklahoma and Arkansas: Possible signatures of induced seismicity. Bulletin of the Seismological Society of America, 103(5), 2850-2861.

SCHOOL OF EARTHSCIENCES